

# Simulations Update

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- ❖ Update on the Liquid Scintillator analysis
- ❖ Comparison Scintillator – RPC
- ❖ First look at the totally active detector

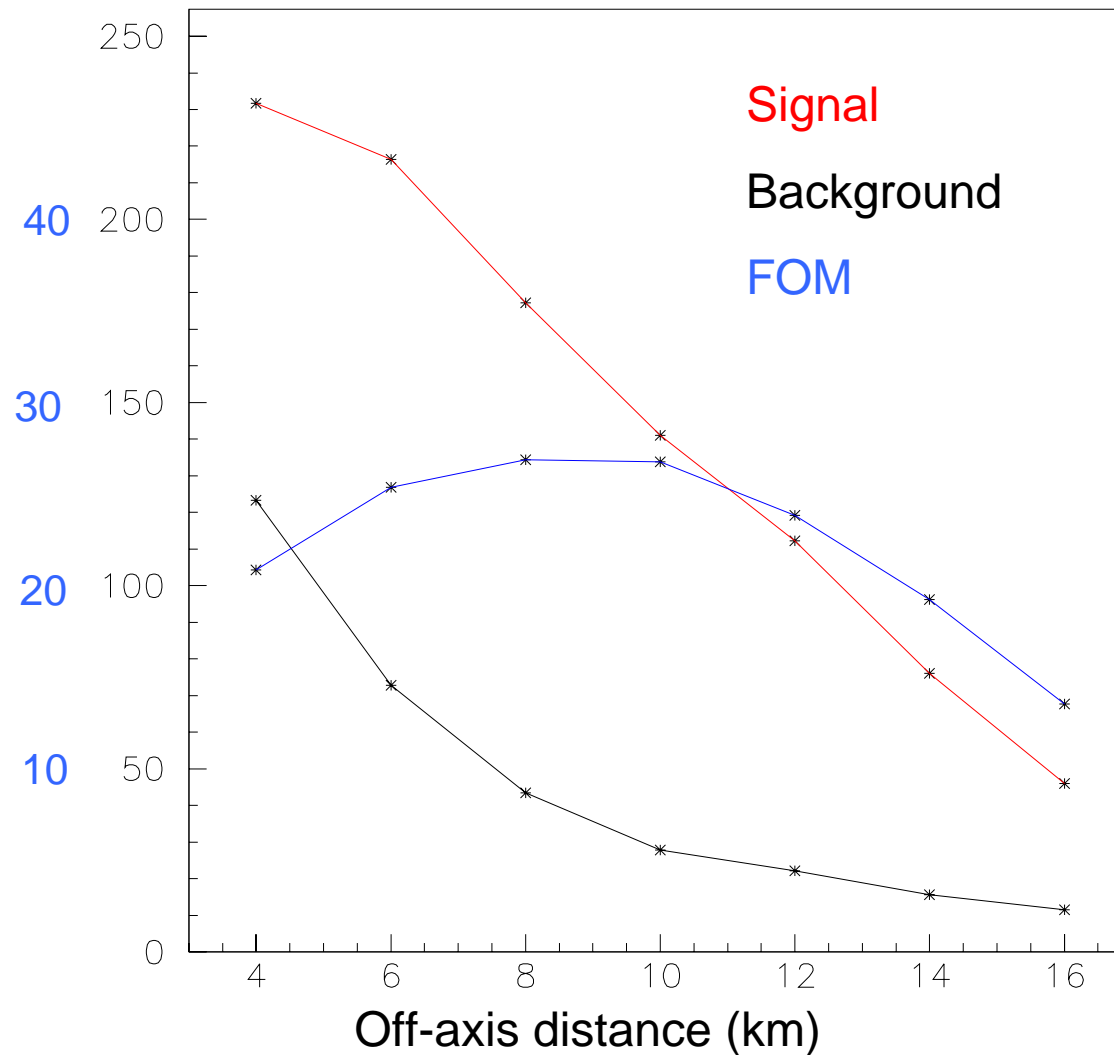
# Liquid Scintillator Update

❖ Nothing very new since the proposal

- Fixed a small number of bugs/problems
- Biggest was to correct the containment volume which had not been changed when the strip length changed from 15.00m to 14.63m (changed dimensions to feet!!).
- Result was that too few events were being rejected for containment.
- FOM went down because of fewer total events and up because more background than signal is rejected by containment.
- Overall a small reduction ( $\sim 1.6$ ) in the best FOM1 at 10km after reoptimisation.

# FOM, signal, background v dist

FOM Events



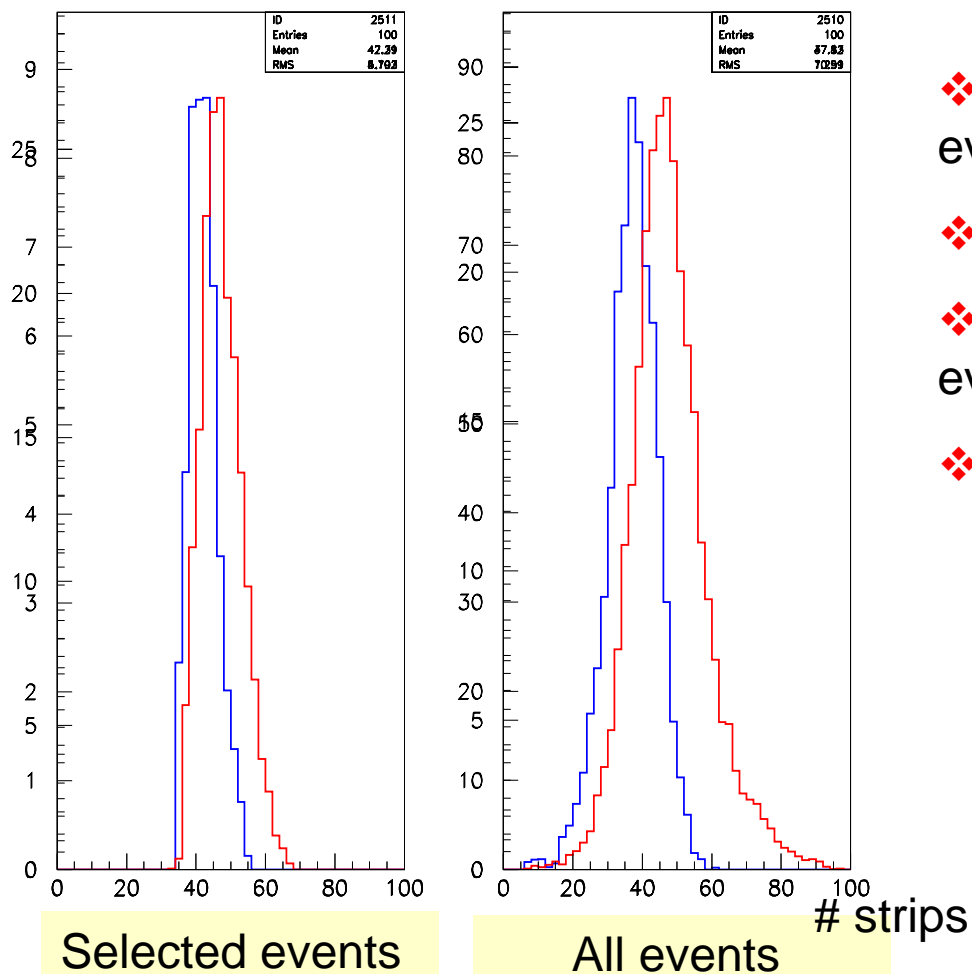
# Scintillator – RPC Comparison

- ❖ Objective: Fair comparison of the scintillator and RPC detectors.
  - Compare a scintillator detector without pulse height to a 1 dimensional readout RPC detector. Should be directly comparable.
  - The gain from pulse height and 2 dimensional readout respectively can then be added to any basic difference.
- ❖ Generated Scintillator and RPC data are run through as close as possible identical reconstruction and selection programs.
  - Ron and I have exchanged data in the form of x/y,z coordinates.
  - The RPC data has run through my reconstruction and analysis system with only very minor changes.
  - Ron will report on his analysis of the scintillator data.

# Differences

- ❖ The only major difference I have found is that the RPC data has more hit strips and more hits/plane presumably due to the charge spreading on the readout strips
- ❖ The containment cut removes a few more events in the RPC data than the scintillator data.
  - partly due to the cross-section area of the RPC detector being slightly smaller
  - probably mostly due to the extra hit strips outside the containment volume due to charge spreading
- ❖ Fraction of  $\nu_e$  CC events kept after reconstruction and containment
  - RPC 65%
  - Scintillator 69%
- ❖ Not optimized for the RPCs, could possibly be improved

# Hit resolutions



❖ Number of hit strips for  $\nu_e$  cc events with  $2.0 < E_\nu < 2.2$  GeV

❖ Blue Scintillator Red RPC

❖ Left selected events, Right all events

❖ Resolution (RMS/mean)

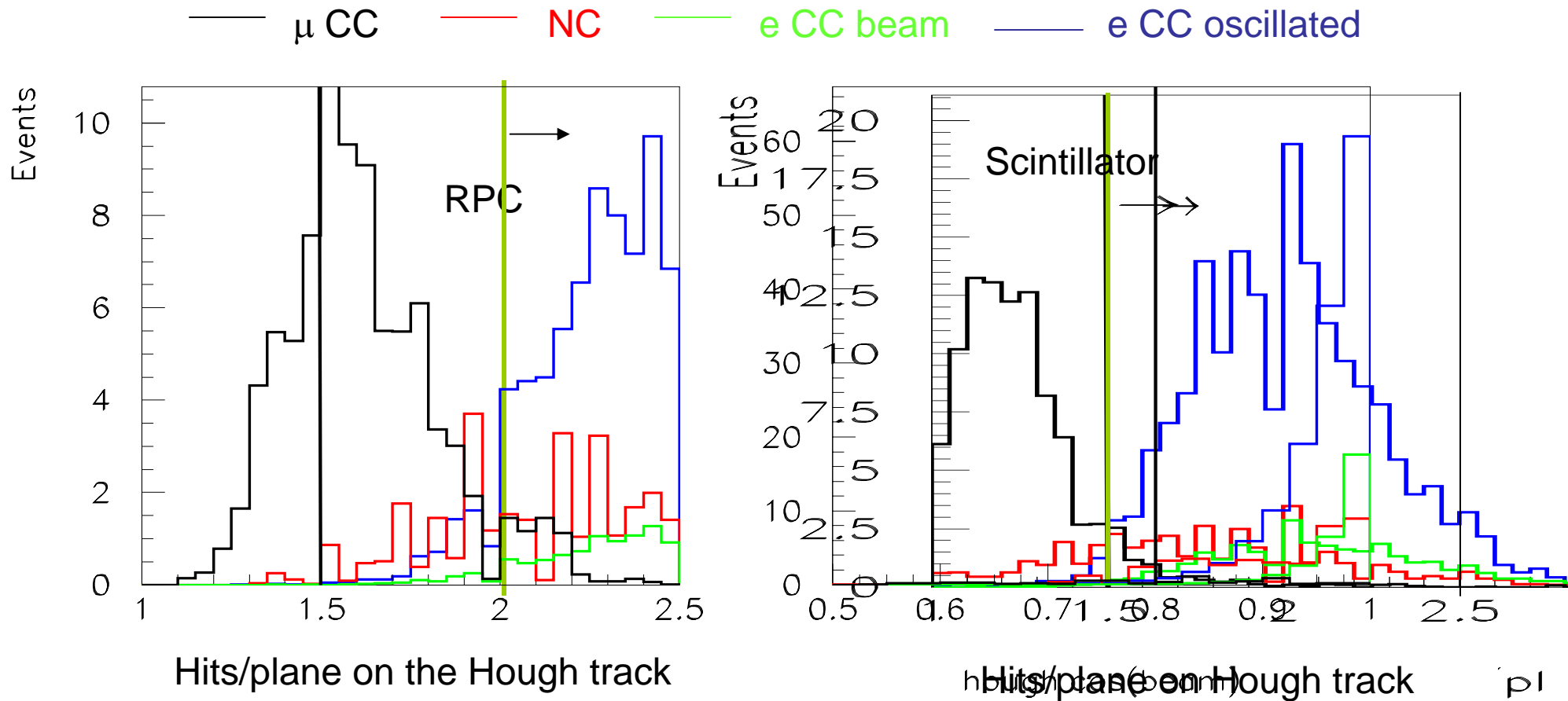
➤ RPC All 22.8%

➤ RPC selected 12.2%

➤ Scintillator all 19.5%

➤ Scintillator selected 9.7%

# Hits/plane on the Hough track



❖ More hits/plane on the selected Hough track on the RPC data, slightly better separation on the scintillator data.

# Results

	$\mu$ CC	NC	e beam	Signal	Back -ground	FOM1	FOM2
RPC      Me Ron	0.5	11.2	14.5	107.6 112	26.2 34	21.0 19.3	9.3
Scintillator Me no PH      Ron	2.0	12.3	16.3	134.6 123	30.6 34	24.3 21	10.5
Scintillator with PH	1.8	11.3	14.7	141.0	27.8	26.8	10.8

❖ Each case optimized for the best FOM1.



# Totally Active Detector

❖ Leon Mualem has generated events in a totally active detector, same types as for the liquid scintillator detector.

➤ 25 ktons

➤ 17.5m x 17.5m x 98m

➤ 1000 x and 1000 y liquid scintillator planes, no absorber

➤ Scintillator strips 4.9 x 3.9 x 1750 cms

➤ Read out from one side as in the proposal detector.

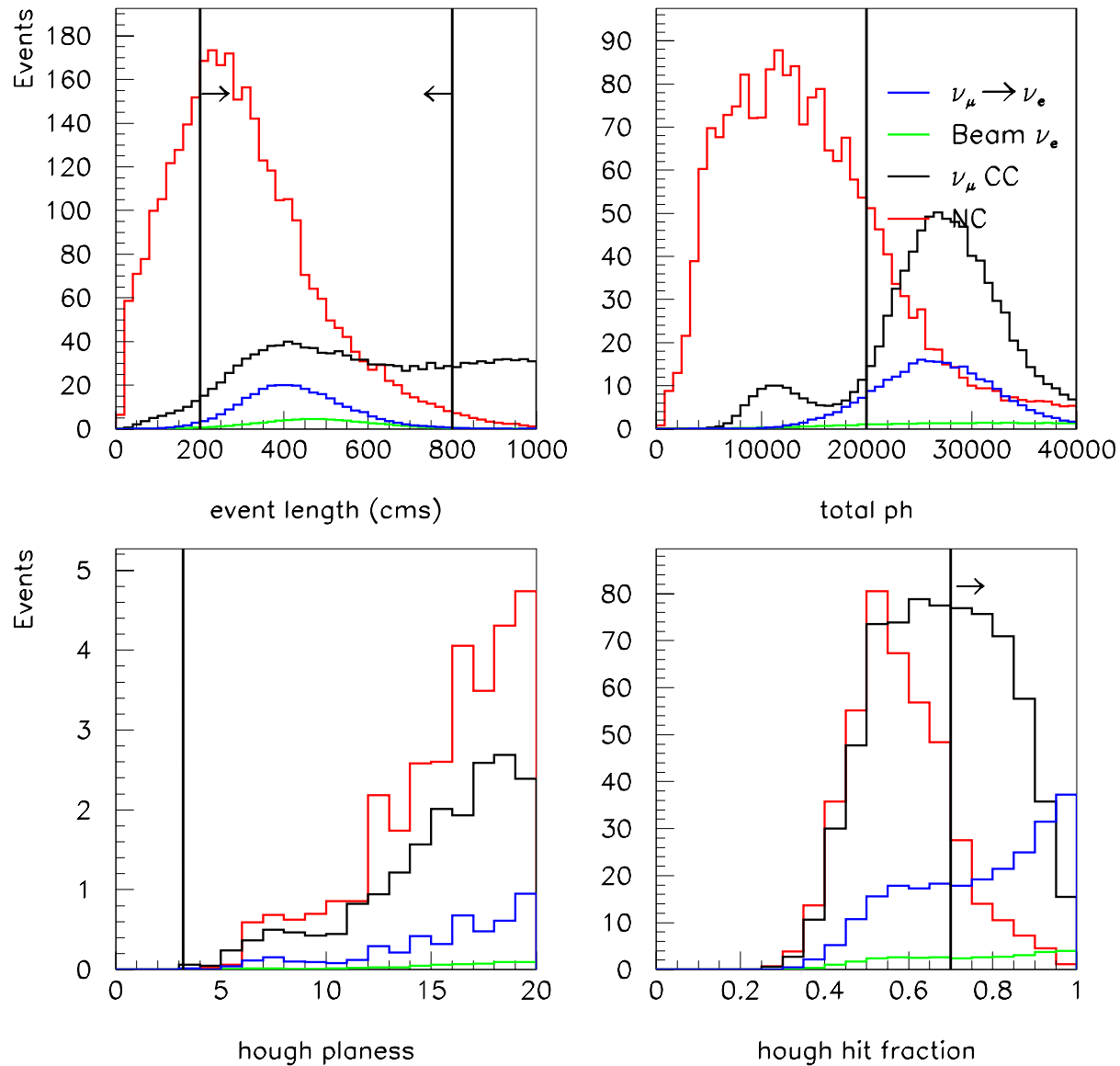
❖ Reconstructed with the same algorithms as for the proposal, only very minor modifications required.

❖ Analyzed with the same variables and cuts as for the absorber detector

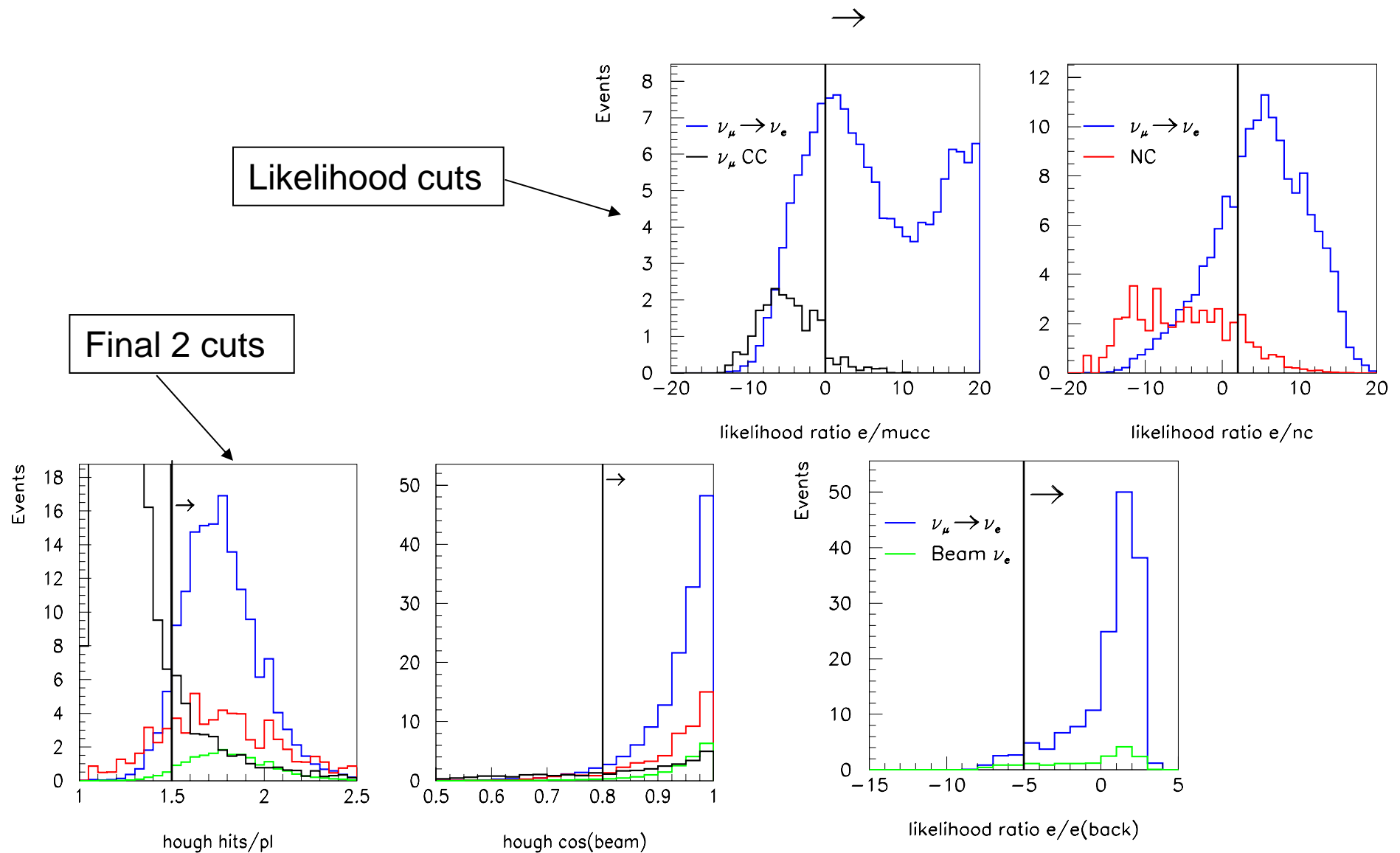
# TA Analysis

- ❖ Very preliminary analysis
  - Smallish statistics ~300K events/type
  - Only training sample, no test sample
  - Limited optimization
- ❖ Detector 10km off-axis
- ❖ 5 years at  $3.7 \times 10^{20}$  pot/year
- ❖ Main changes from standard detector
  - Pulse height cuts
  - Containment region, much smaller as harder to escape unseen from totally active detector

# TA detector plots



# TA detector plots



# Results


Test	$\mu$ cc	nc	e beam	signal
Oscillated events	2874	5429	114	426
Reconstructed events	2807	4234	108	405
Containment	1816	3317	79.4	303
Event length	930	2245	74.7	289
Total ph	728	427	32.1	243
Hough fraction	334	65.6	18.7	156
Hough hits/plane	31.2	51.3	17.6	144
Beam angle	20.3	46.4	16.8	137
Likelihood cut	1.20	5.95	9.58	87.4

	Signal	Background	FOM1	FOM2
TA 125kton-year	87.4	16.7	21.4	8.6
SD 250kton-year	141.0	27.8	26.8	10.8

# e CC event

Run 20010 Evt 41

raw  
photo-  
electrons



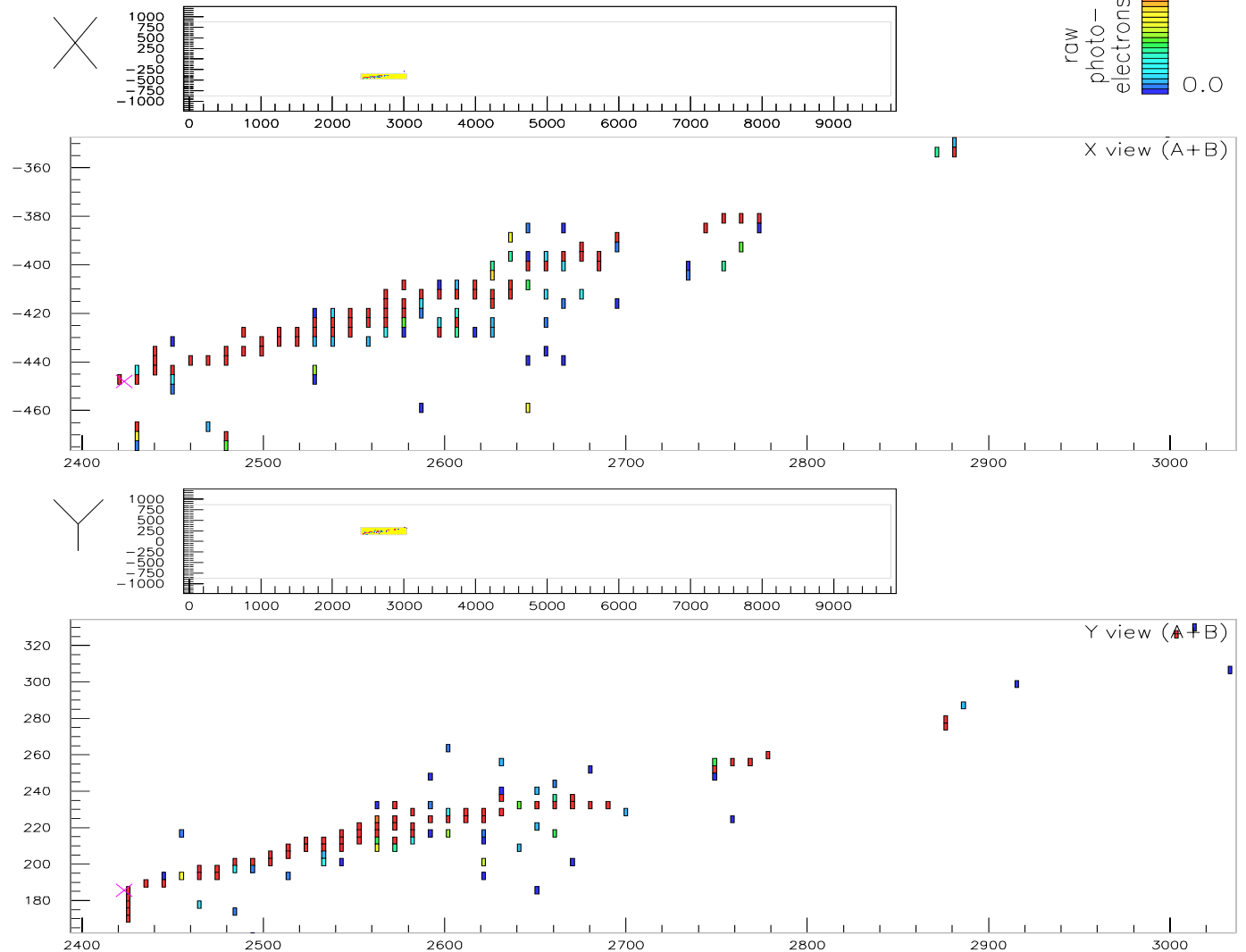
$$\nu_e p \rightarrow e^- p \pi^+$$

$$E_\nu = 2.5 \text{ GeV}$$

$$E_e = 1.9 \text{ GeV}$$

$$E_p = 1.1 \text{ GeV}$$

$$E_\pi = 0.2 \text{ GeV}$$



# $\mu$ CC event

$$\nu_{\mu} n \rightarrow \mu^{-} n \pi^{+} \pi^{0}$$

$$E_{\nu} = 2.8 \text{ GeV}$$

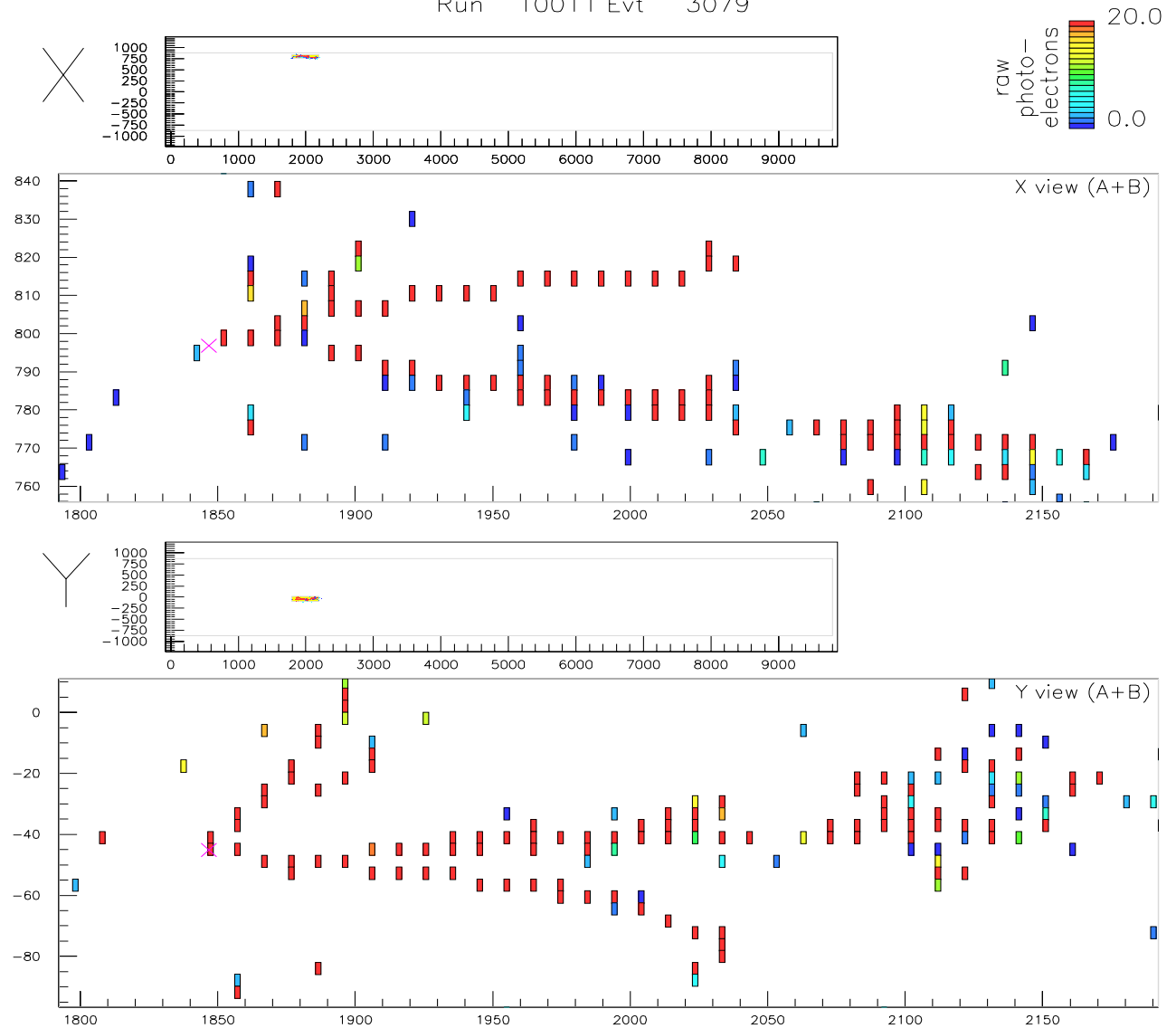
$$E_{\mu} = 0.5 \text{ GeV}$$

$$E_n = 1.0 \text{ GeV}$$

$$E_{\pi^{+}} = 0.4 \text{ GeV}$$

$$E_{\pi^0} = 1.8 \text{ GeV}$$

Run 10011 Evt 3079



# NC event

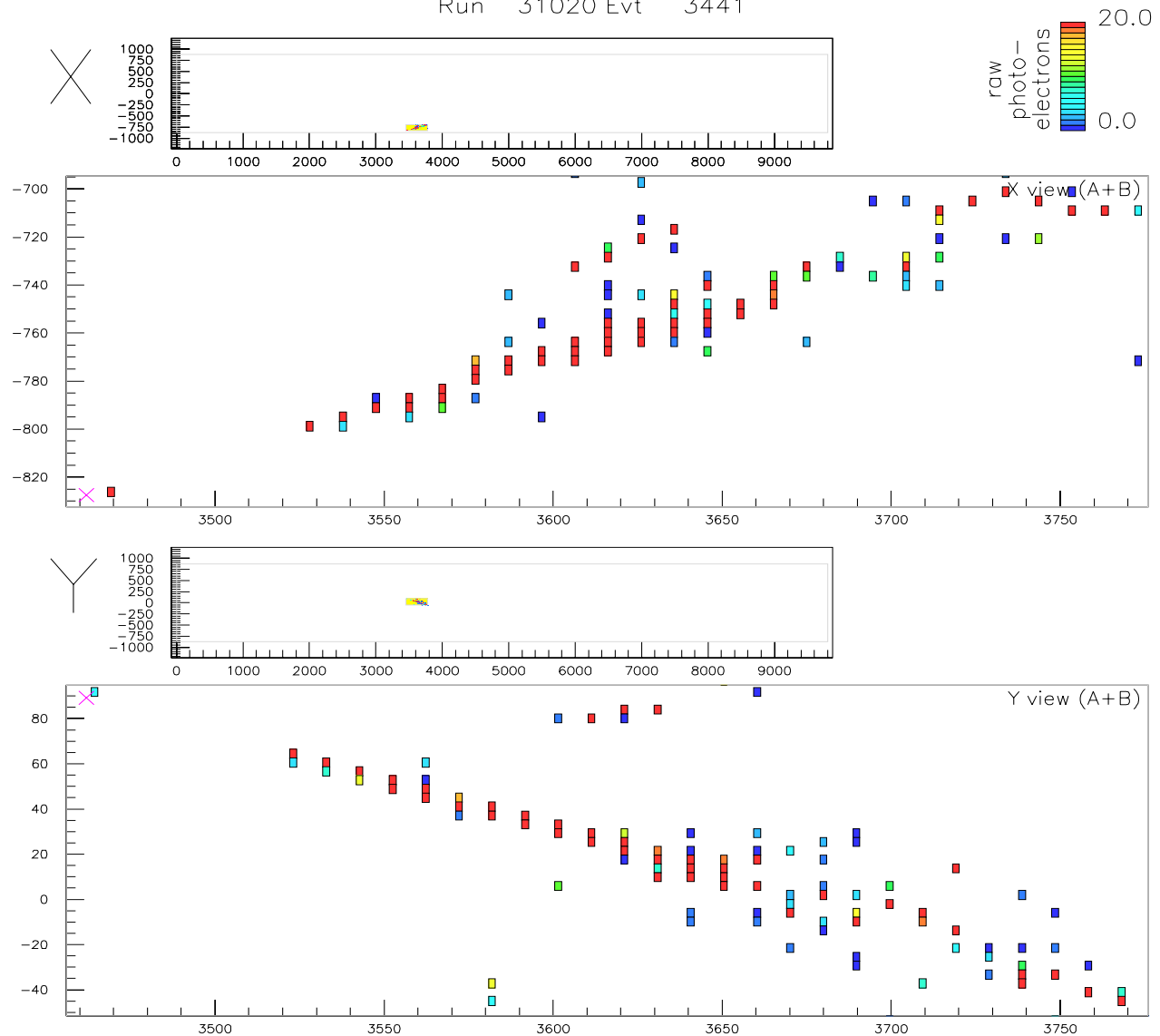
Run 31020 Evt 3441

$$\nu_{\mu} N \rightarrow \nu_{\mu} p \pi^0$$

$$E_{\nu} = 10.6 \text{ GeV}$$

$$E_p = 1.04 \text{ GeV}$$

$$E_{\pi^0} = 1.97 \text{ GeV}$$





# Coherent $\pi^0$ event

$$\nu_\mu N \rightarrow \nu_\mu \pi^0 N$$

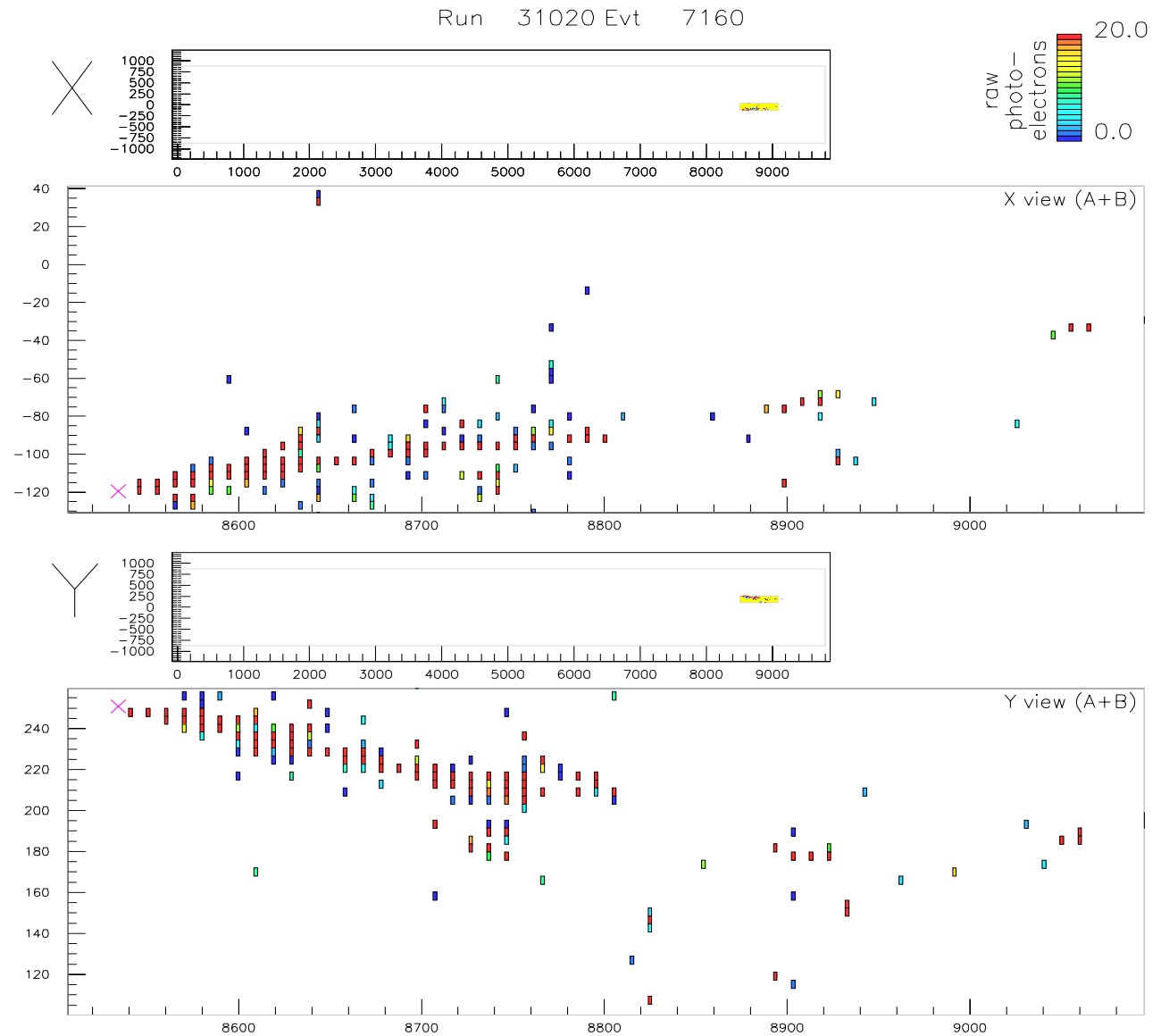
$$\rightarrow \nu_\mu e^+ e^- \gamma N$$

$$E_\nu = 9.9 \text{ GeV}$$

$$E_{e^+} = 0.1 \text{ GeV}$$

$$E_{e^-} = 0.4 \text{ GeV}$$

$$E_\gamma = 2.1 \text{ GeV}$$



# Comments

- ❖ Having scanned a small number of events my guess is that between  $1/3$  and  $1/2$  of the selected background events are in principle distinguishable from e CC events.
- ❖ If we succeeded in doing this by exquisite programming (or scanning), the FOM would be  $\sim 30$ , better than the absorber detector. But we can probably also improve the absorber detector with exquisite programming.
- ❖ This analysis is still essentially selecting only quasi-elastic or low- $y$  events. The selection efficiency is only 29% of reconstructed contained events.
- ❖ To do significantly better we would need to recognize e CC events with a significant hadron shower.
- ❖ I am sure that this analysis can be improved and thus I suspect that a 25kton totally active detector would have at least equivalent sensitivity to the 50kton detector with absorber.